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Evaluation of a 2-Active Ingredient Gas Cartridge for Controlling Northern Pocket Gophers

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ABSTRACT

The efficacy of a four-ingredient (two active and two inert) gas cartridge to control northern pocket gophers in an oat–alfalfa hay field was evaluated. The reformulated rodent gas cartridge was jointly developed by the Denver Wildlife Research Center and Pocatello Supply Depot to replace the currently registered eight-ingredient gas cartridge. The reformulated cartridge contains sodium nitrate and charcoal as active ingredients, with Fuller's earth and borax as inert ingredients. When ignited, the active ingredients produce primarily carbon monoxide. Four test areas (one control and three fumigated) were randomly established with 15 sample plots (each 0·008 ha) on each test area. Active burrow systems were treated: (1) in the sample plots; (2) outside the sample plots but within each test area; and (3) in the buffer zone around each test area. Pocket gopher activity on each plot was determined pre- and post-testing by an open-hole index. Although there was an increase in pocket gopher activity on the control test area and declines of 7·1, 13·3 and 30·8% on the three test areas receiving the gas cartridges, the difference in activity was not statistically different ($p = 0{\cdot}174$)*. The 17·1% mean reduction in pocket gopher activity in the fumigated test areas was substantially below the minimum standard efficacy of 70% established by the U.S. Environmental Protection Agency for fumigants. This result was similar to two previous studies* *conducted with the original eight-ingredient gas cartridge for the control of northern pocket gophers.*

INTRODUCTION

The Animal and Plant Health Inspection Service (APHIS), an agency of the United States Department of Agriculture (USDA), has registrations with the United States Environmental Protection Agency (USEPA) for two gas cartridges — one for the fumigation of several species of burrowing rodents, the other for coyotes in dens (Ramey *et al.*, 1992). These cartridges are effective pyrotechnic fumigants for the underground control of several vertebrate pests. Upon ignition of a cartridge, the active ingredients burn vigorously to produce primarily carbon monoxide gas (Savarie *et al.*, 1980; USEPA, 1991) — a preferred euthanatizing agent (American Veterinary Medical Association, 1993). Inert ingredients in the gas cartridge afford safety to the user by extending the time before the heat and flame from the cartridge's combustion can ignite the walls of the paper tube holding the contents.

In 1989, the USEPA announced the data requirements to reregister the four active ingredients in APHIS's currently registered eight-ingredient rodent gas cartridge (USEPA Reg. no. 56228-2). Because the reregistration data requirements were so extensive and costly, the Animal Damage Control (ADC) program decided to develop a reformulated rodent gas cartridge and amend the registration using only two active ingredients (sodium nitrate and charcoal) (Ramey *et al.*, 1994) and two inert ingredients (Fuller's earth and borax) (Savarie & Blom, 1993). The reformulated gas cartridge was developed jointly by the Denver Wildlife Research Center (DWRC) and Pocatello Supply Depot (PSD). Although pocket gophers are claimed as a target species for the eight-ingredient gas cartridge, efficacy was not demonstrated in two studies evaluating its control of northern pocket gophers (*Thomomys talpoides*). In one study, Sullins & Sullivan (1993) reported only an 8% reduction in pocket gopher activity after fumigating 20 pocket gopher burrow systems with one cartridge in each; in the other study, Rost (1987: U.S. Fish and Wildlife Service unpublished report) recorded reductions of 15, 22 and 30%, with a mean reduction in pocket gopher activity of 22% using one gas cartridge on each side of the fork at the entrance in 20 fumigated burrows. However, the reformulated gas cartridge has not been evaluated for this application; therefore, this report summarizes the results of an efficacy study with the reformulated gas cartridge on a population of northern pocket gophers in an oat–alfalfa hay field.

METHODS AND MATERIALS

Study site

A study site was selected within the range of the northern pocket gopher, northwest of Wellington, Larimer County, Colorado (T10N, R68W, northeast quarter of Section 31) about 1661 m (5449 ft) above sea level. The study site was a circular 44·5 ha (110 acre) oat–alfalfa hay field that was established in April 1994 and irrigated by a center-pivot sprinkler system.

Gas cartridge formulation

The PSD (Pocatello, Idaho) manufactured the reformulated gas cartridges according to manufacturing procedure MP-1 (USEPA Establishment no. 56228-ID-1) using two active ingredients: sodium nitrate (53%) and charcoal (28%) and two inactive ingredients: borax (9%) and Fuller's earth (10%). Tap water was added to suppress dust during the mixing and filling of the cartridge tubes and to serve as a compactor. The water evaporated in 7–10 days, leaving a solid core of material inside the paper tube. Cartridges had a mean net dry weight of 144·6 g (SD = 5·4, $N = 30$). Six randomly selected cartridges were assayed for concentrations of active ingredients (nominally 53% sodium nitrate and 28% charcoal). These analytical results indicated that the mean percentage of sodium nitrate (±SD) was 56·9% (±0·73) and charcoal was 28·2% (±1·27%), both within the USEPA's certified limits.

Pocket gopher activity measurements (open-hole index)

Pocket gopher activity both pre- and post-test was measured by the open-hole index method (Richens, 1967; Barnes *et al.*, 1970) on the 0·008 ha (1/50 acre) sample plots located on each of the test areas. The open-hole method has been shown to be a reliable activity measure for northern pocket gophers (Engeman *et al.*, 1993). It measures the presence or absence of a pocket gopher within an underground burrow system by relying on the pocket gopher's propensity to close any open burrow. Burrow occupancy was evaluated by creating an access to the burrow, by either opening a closed entrance (mound or feeder plug) on the surface or if the entrance could not be located then the ground around a mound or feeder plug was probed with a metal rod until a tunnel system was located and an opening was created. After 48 h, burrow openings were examined to determine if the pocket gophers constructed soil plugs that closed the opened burrows. The burrow system and corresponding sample plot were classified as active if the hole was closed (i.e. soil plug). The burrow system was classified as inactive if the burrow remained open. If all burrow systems were inactive, then the sample plot was classified as inactive.

Test area establishment and pre-testing open-hole index

On September 19, 1994, test areas were established within an oat–alfalfa hay field. Each square test area, measuring 0·40 ha (1 acre), was surrounded by a buffer zone. The buffer zone was defined as a square area constructed by extending the outer edges of the test area 27·4 m (90 ft). Therefore, the outside boundaries of the buffer zone measured 118·4 m (388·45 ft) or 1·4 ha (3·46 acres). A minimum distance of 90 m (295 ft) separated each test area and its buffer zone from other test areas and their respective buffer zones.

The day after the four test areas and their buffer zones were established in the oat–alfalfa hay field, all pocket gopher signs were erased by leveling the mounds with a hand rake and scraping soil over the feeder plugs. Six days later, the pre-test open-hole index was initiated. On each of the four test areas, 15 circular sample plots were established in areas containing fresh mounds or feeder plugs. Sample plots had an area of 0·008 ha (1/50th acre) and a radius of 5·12 m (16·80 ft). The center of each sample plot was marked with a numbered wire-stem flag; the boundaries of sample plots did not overlap. On each sample plot, all the burrow systems with fresh mounds or feeder plugs were opened. The number of fresh mounds or feeder plugs opened per sample plot ranged from 1 to 10. After 48 h, the opened burrow systems in each sample plot on the four test areas were examined for evidence of closure by pocket gophers. Sample plots were classified as active or inactive, and the pre-test open-hole index was calculated as % change in sample plot activity pre- vs. post-testing.

Fumigation of burrows and post-testing open-hole index

The gas cartridges were equipped with fuses and used according to label directions. Three of the four test areas were randomly designated to receive gas cartridge treatment. The other test area served as a control. On September 29, 1994, fumigation with the cartridges began at 0830 h and ended about 1700 h on the three test areas. Afterwards, the active burrow systems in the control test area were opened and then reclosed.

The gas cartridge application was conducted systematically to ensure that each active pocket gopher burrow system within the test area and its buffer zone were treated. Placement of each cartridge began by first probing at active pocket gopher mounds or feeder plugs with a metal rod or trowel to locate the tunnel system. After locating the tunnel and before igniting the fuse, the gas cartridge was inserted into the burrow system for fit and then withdrawn to ensure its placement. After igniting the fuse, the cartridge was immediately inserted 5·1–7·6 cm (2–3 inches) into the burrow. Time (~20 s) was allowed for verification that the fuse ignited the cartridge before the entrance was sealed with soil. Each gas cartridge inserted on the sample plots was recorded. If any burrow entrance contained two or more tunnels, each tunnel received a gas cartridge. Table 1 presents the number of gas cartridges applied to each active mound or feeder plug per sample plot for each test (fumigation) and control area.

The sequence of insertion of the gas cartridges into the burrow systems on the test areas, was as follows: first, the sample plots; second the active sites outside the sample plots but within the test area; and last, the active sites in the buffer zone. On the control test area, the entrances to the active mounds or feeder plugs were opened and then immediately sealed. The sequence of burrow opening and closing was the same for the control test area as for the test areas receiving the gas cartridges.

The day after the gas cartridge application, the post-test open-hole measurements were made. On the three fumigated test areas, only the burrow systems on the sample plots were reopened that had received a gas cartridge. On the control test area, only the burrow systems on the sample plots were reopened that had been previously reopened, and then closed on the day of fumigation. In addition, fresh mounds constructed since fumigation were also opened on all four test areas. Upon opening the burrow system, gas cartridges were evaluated for completeness of burn and proper insertion. Combustion of cartridges was complete (100%) and

TABLE 1
Number of Northern Pocket Gopher Burrows Treated and Gas Cartridges used for Sample Plots on Each Test Area

Test area	*Active sites on the sample plots*	*Active sites outside the sample plots*	*Active sites in the buffer zone*	*Total burrows*	*Total cartridges*
1	40	27	95	161	162
2	35	15	128	178	178
3*	45	28	73	146	0
4	53	35	96	184	184
Totals:	173	105	392	669	524

only a yellowish-white solid incombustible material remained; no evidence of unburned paper tubes or endcaps was observed. Because three of 173 cartridges had been inserted in sealed burrows on the sample plots, the data from sample plot #2 (test area 1) and sample plots #16 and #17 (test area 2) were not included in the open-hole index statistical analysis for pre- or post-testing. After 48 h the opened burrow systems were examined for evidence of closure by pocket gophers. Pocket gopher open-hole activity was estimated by the percentage of sample plots showing activity. Fisher's exact test was used to analyze differences in open-hole pocket gopher activity, between the control test area and the three fumigated test areas (Sokal & Rohlf, 1981).

RESULTS

Pre-test open-hole index

After 48 h, pocket gophers were active on 59 (98·3%) of the 60 sample plots. The one inactive sample plot was observed on the control test area, where two mounds each having one burrow system remained open (Table 2). Overall, pocket gophers closed 180 (95·2%) of the 189 holes opened on the 134 mounds or feeder plugs on the sample plots, during the pre-test period.

TABLE 2
The Number of Active and Inactive Sample Plots Pre- and Post-treatment and Change in Open-Hole Activity for Each Test Area (TA)

	Total no. of sample plots	*Active sample plots*	*Inactive sample plots*	*% Change in sample plot activity (pre- vs. post-testing)*
TA-3 Control				
Pre-testing	15	14	1	+6·7%
Post-testing	15	15	0	
TA-1 Gas Cartridge				
Pre-testing	14	14	0	−7·1%
Post-testing	14	13	1	
TA-2 Gas Cartridge				
Pre-testing	13	13	0	−30·8%
Post-testing	13	9	4	
TA-4 Gas Cartridge				
Pre-testing	15	15	0	−13·3%
Post-testing	15	15	2	

Post-test open-hole index

Table 2 compares pre- and post-test pocket gopher sample plot activity and % change after fumigation by test area. Pocket gophers were active on 35 (83·3%) of the 42 sample plots following fumigation, and they closed 80 (65·6%) of the 122 burrows that had been opened on the three test areas. On the control test area, all 15 sample plots were active; pocket gophers closed 42 (97·7%) of the 43 burrows that had been opened. Post-treatment, pocket gophers closed all open burrows on 21 (50·0%) of the 42 sample plots. Fumigation did not produce a reduction in activity in excess of 31%; it averaged 17·1% on the three test areas (Table 2). Differences in proportions of open-hole activity between control and test areas were not detected using Fisher's exact test ($p = 0{\cdot}172$).

DISCUSSION

The lack of efficacy of the reformulated gas cartridge indicates it is not a practical management tool for reducing northern pocket gopher populations on crop/rangeland, and its does not meet the 70% minimum standard the USEPA has established for verifying the efficacy of fumigants (USEPA, 1982). Studies with other fumigants have also failed to achieve the 70% reduction in pocket gopher populations specified by USEPA (1982). In California, when methyl bromide, chlopicrin and nitrocellulose film bombs were placed in pocket gopher burrows (species not specified), activity declined about 50% with each of the three compounds (Miller, 1954). Miller also tested two other compounds that were even less effective — hydrocyanic acid gas, generated by applying moistened calcium cyanide powder or incorporating calcium cyanide into a bomb, and carbon bisulfide. Blonk (1951) reported that calcium cyanide powder was more effective in killing pocket gophers when blown into a tunnel system with compressed air than injecting it with a hand pump. He estimated that compressed air carrying the calcium cyanide powder traveled 45·7 m (150 ft) in the tunnel system in 1·5 min. The degree of control was not specified, but this method has replaced trapping to control pocket gophers along canal banks (Blonk, 1951). Plesse (1984) reported that the exhaust from a gasoline engine and the gases generated by the eight-ingredient gas cartridge were lethal to valley pocket gophers (*Thomomys bottae*), but no mortality data were presented. Auto engine exhaust, pumped into burrow systems of plains pocket gophers (*Geomys bursarius*), killed 11 of 13 radio-collared animals in Texas (Matschke, unpublished data).

Miller (1957) contended that several factors contributed to pocket gopher survival following treatment with fumigants. First, the extreme length, volume and shape of the burrow system with its network of side tunnels may affect the diffusion of the toxic gas and reduce concentrations below lethal levels for the species. Second, the tunnel system is a closed system and contains dead air that may delay the diffusion of the toxic gas, making it difficult to move through the tunnel system, even under pressure. Therefore, unless a gopher is overcome immediately, the time lag required for the gas to infiltrate the entire tunnel system may allow the pocket gopher to move to a remote part of the burrow and/or plug the tunnel. Third, the toxic gas may be lost to absorption by the moist or porous soil lining the tunnel. Therefore, Miller (1954) postulated that fumigants were ineffective because toxic gases did not reach the pocket gopher in its extensive burrow system at a lethal concentration.

In this reformulated gas cartridge study, a lethal concentration of carbon monoxide evidently failed to reach most of the pocket gophers. Miller (1957) presented data on the air volume in the burrow systems of valley pocket gophers indicating a mean of $0{\cdot}11\,m^3$ and a range from $0{\cdot}03$ to $0{\cdot}22\,m^3$. We used this information to examine the relationship between the quantity of carbon monoxide (CO) generated by the two-ingredient gas cartridge and the volume of the pocket gopher burrow systems. The CO generated by burning one cartridge in a $0{\cdot}11\,m^3$ burrow system would occupy 29% of the volume of this hypothetical system, and represent 290,000 ppm of CO. Burning a single cartridge in the largest burrow system of $0{\cdot}22\,m^3$ would represent a concentration of 144,000 ppm of CO. No LC_{50} for CO exists for the northern pocket gopher, but the LC_{50}s for the three other rodent species are 1807 ppm (rat), 2445 ppm (mouse) and 5720 ppm (guinea pig) (Rose *et al.*, 1970). The theoretical maximum production of carbon monoxide for the reformulated 144·6 g gas cartridge was calculated at 1·35 moles by our colleague, J. Johnston. The volume that 1·35 moles of CO would occupy at 20°C and at 1 atmosphere (sea level) is 32·5 liters or $0{\cdot}03\,m^3$. These data suggest the reformulated gas cartridge should generate sufficient CO, in relation to the probable size of the burrow system, to be lethal to northern pocket gophers. Northern pocket gophers are about half the size of valley pocket gophers and thus a smaller diameter burrow system would be expected. Therefore, it is apparent that factors other than the quantity of carbon monoxide generated by the gas cartridge, most probably those outlined earlier by Miller (1957), contributed to the survival of northern pocket gophers in this study.

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